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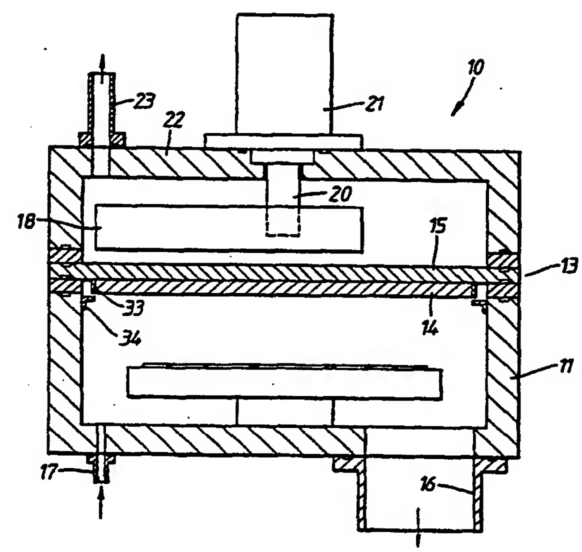

(57) Abstract

This invention relates to magnetron sputtering apparatus, generally indicated at (10), comprising a vacuum chamber in which is disposed a support (12) for semi-conductor wafers and a cathode (13) bearing target material (14). A magnetic array (18) is mounted for rotation external to the chamber (11) to create a non-zero field at or adjacent any point on the target during a cycle of the array, which can be rotated about an axis (19) by means of a motor (21).

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Sputtering Apparatus

This invention relates to magnetron sputtering apparatus.

It is well-known to use a magnetic field to enhance the number of collisions between ions and a sputter target. Proposals have been made for rotating the magnets with respect to the target in order to spread the area of impact and typically the result is that a circular, erosion zone is sputtered out of the target. This is very wasteful in terms of material and has serious implications from the point of view of contamination because those areas which experience a low level of impacts tend to become contaminated with one or several of the materials which make up the target material.

Various proposals have been made for spreading the area of enhanced ion impact and hence sputtering but they have not proved particularly satisfactory and often leave a central area which is effectively untouched.

There are many arrangements for causing the rotation of the magnetic array and to the best of the Applicants knowledge they all include the use of the cooling fluid to drive the magnetic array. This results in many sealing problems and also means that the rate of rotation cannot be independent of the rate of cooling and rotation at high speed is impractical.

From one aspect of the present invention consists in a

magnetron sputtering apparatus including a vacuum chamber, a target mounted on a platen, the target being disposed in the vacuum chamber on one side of the platen, a magnetic array mounted for rotation about an axis adjacent the other side of the platen, the array being so configured and disposed relative to the target such that the magnetic field on the one side of the target at the axis of rotation is non-zero.

In a preferred embodiment the component of the magnetic field parallel to the target (B_H) surface in the direction of increasing absolute field is at least 30% of the orthogonal field component (B_V) and frequently should be greater than 50% of B_V.

The relative strengths of B_H and B_V will depend on the total field strength, the pressure within the chamber and the magnitude of the bias voltage applied to the target. For a field strength of 100 to 300 guass B_H is generally desired to be more than 50% of B_V.

In a particularly preferred embodiment the array is constructed such that at some stage in each cycle the horizontal component (B_H) of magnetic field on the sputtered side of the target at every point of the target is non-zero and generally B_H is at least 30% of B_V at all points at some time during the cycle and it may be at least 50% of B_V.

The target may be generally circular in which case it may be co-axial with the axis of rotation and the array may be eccentric with respect to the axis. Alternatively the

be eccentric with respect to the axis. Alternatively the array may be mounted for planetary motion about the axis or for a combination of linear and rotational movement relative to the axis.

The magnetic array may have inner and outer generally D-shaped pole pieces, in which case the axis of rotation preferably passes through close to the edge of the inner pole piece.

In another arrangement the magnetic array may comprise a plurality of pairs of pole pieces which sweep out circular tracks when they are rotated, the respective tracks being co-axial and circumjacent.

In a preferred embodiment the magnetic array is disposed outside the vacuum chamber and is rotated directly by a motor. In this case the platen carrying the target may form at least part of the wall of the vacuum chamber and may be in the form of a heat sink. The magnetic array may be mounted in its own separate support chamber, which can be partially evacuated to reduce the pressure drop across the platen and hence reduce the size required by the platen.

From another aspect the invention consists in a magnetron sputtering apparatus including a vacuum chamber, a target disposed in the chamber, a magnetic array for forming a tunnel-shaped field passing through the target and a motor for rotating the array, the motor and the array being disposed outside the chamber.

Preferably the target is mounted on a heat sink platen

which forms at least part of the wall of the chamber and the platen may be formed with an internal network of cooling passages.

The invention may be performed in various ways and specific embodiments of which will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a part diagrammatic vertical section through a magnetron sputtering apparatus;

Figure 2 is a diagrammatic view from above of a magnetic array for use in the apparatus of Figure 1;

Figure 3 is a further embodiment of a magnetic array;

Figure 4 illustrates a still further embodiment of a magnetic array; and

Figure 5 illustrates an alternative "three dimensional array".

The general principles of magnetron sputtering are well-known and so will not be described in detail in this specification. Broadly the sputtering apparatus, generally indicated at 10, comprises a vacuum chamber 11 in which is disposed a support 12 for semi-conductor wafers or other substrates and a cathode 13. The cathode 13 comprises a layer of target material 14 and a heat sink platen 15, which may be provided with an internal cooling circuit (not shown). The platen 15 forms part of one wall of the vacuum chamber 11.

As is usual the sputtering apparatus 10 is provided

with a port 16 for evacuating the chamber and a further port 17 for introducing the plasma gas. Means (not shown) for inducing the necessary electrical charges to strike the plasma within the chamber are provided. In order to enhance the impact of the plasma ions on the target 14 the magnetic field is created which passes downwardly through the surface of the target, then parallel to the face of the target and finally back through it. Electrons are captured in this tunnel-shaped field and, under the influence of the magnetic and electric fields, collide with the gas atoms to produce ions. These ions are drawn down on to the face of the target in the area where the tunnel-shaped field extends through the target.

In the apparatus of Figure 1 such a magnetic field is created by a magnetic array 18 which is mounted for rotation about an axis 19 on the shaft 20 of a motor 21. It will be noted that the array 18 is eccentric with respect to the axis 19 which in turn is co-axial with the target 14. The design of the array 18 is such that for one cycle of operation the magnetic field adjacent any point in the target will be non-zero and will preferably be within the conditions for B_V and B_H mentioned above. In particular the axis of rotation should always pass through a point of non-zero field so as to ensure that there is no dead point on the target. By creating a equal application of the magnetic field to the target surface and by ensuring that all parts of the target surface experience the field during any cycle,

even erosion of the target can be achieved and hence the significant problems of re-deposition are reduced or avoided.

It will be noted that the motor 21 and the array 18 are disposed outside the main vacuum chamber and can be altered and serviced readily without interfering with the vacuum in that chamber.

However if required, the array 18 can conveniently be disposed in a further chamber 22 which can be evacuated through port 23 to a pressure of between 10 and 100 mbars so as to reduce proportionally the forces on the platen 15 and hence its size. A vacuum of this sort can readily be achieved and so the magnetic array 18 can be assessed without causing too much disruption.

The provision of a direct drive gives a number of advantages:a great freedom of choice of the axis of rotation; the ability to rotate the assembly at high speeds; more freedom of choice of the type of rotations and improved reliability and access to the magnetic assembly.

The freedom to choose the axis or rotation and the shape of the magnetic assembly is important in high performance sputtering apparatus to ensure that every part of the sputter target face undergoes nett erosion. Since the target deposition rate under typical conditions is some one tenth the mean erosion rate, target material will tend to deposit on the target surface where erosion is low, causing contamination, particularly by generating particles.

To achieve the nett erosion it is desirable that the axis of rotation is at a point on the magnetic assembly where the field above the target has a parallel component of magnetic field greater than 50% of the perpendicular component. Further, it is also desirable that the magnetic assembly also satisfies the above condition at the edge of the target; this is very difficult to achieve without the fringe fields around the circumference of the target causing spurious discharges in this region. This proposal includes the use of an ancillary pole piece around the periphery of the target to suppress such fringing fields.

In rotating magnetic assembly systems the sputter rate at a point remote from the axis varies greatly during one rotation which causes a similar variation in the deposition rate on the substrate in close coupled systems. Hence, to obtain a circumferential uniformity with only 1% variation requires some 100 rotations during the process; also, high rate of deposition must be maintained for best quality giving thin film process times of a few seconds. These two conditions combine to give a required rotation speed of several hundred revolutions per minute. It is suggested that high rotational speeds are important for the deposition of high quality, reactively sputtered films. This process involves adding a gas which reacts with the material being sputtered, so enabling a compound to be deposited. Many such processes - for example, titanium nitride - operate in a regime where the adsorption on to the target surface and

the sputtering from the surface are in equilibrium for a given film stoichiometry. Should the rate vary, then the stoichiometry will vary. This indicates that the period of rotation should be short compared with the time to form a complete monolayer on the target, and under typical conditions this time is a few milli-seconds, so again rotation speeds approaching several hundred revolutions per minute are required.

Turning to Figure 2 a magnetic array which shows planetary motion is shown. The array 18 comprises a link 24 which is rotatable about the axis 19 which carries a magnet 25 at its other end for rotation about a further axis 26. It will readily be appreciated that for one rotation about the axis 19 the whole area of the target may be swept out. The area swept out by a single rotation about the axis 26 is indicated at 27.

Figure 3 shows an alternative arrangement, for use with a generally rectangular configuration. Here the magnet 25 is mounted on a pair of links 24 which can be rotated about respective axes 28. This array will sweep out the area 29. In an alternative construction only one link may be used with the link and magnet rotating in opposite directions.

Figure 4 illustrates an array 18 comprising inner and outer pole pieces 30,31. Here the axis 19 passes through the inner pole piece. It will be seen that the pole pieces are generally D-shaped although the edge 32 may be to an extent outwardly curved.

Sometimes it is desired to treat a cylindrical surface using a cylindrical target. In this case the magnetic assembly 18 may be indicated in Figure 5.

It will be appreciated that these techniques can be utilised with other arrays and other target shapes.

With any of these arrays problems can be experienced in maintaining the magnetic field adjacent the edge of the target. One solution may be to have an array extending beyond the edge of the target, but preferably, as shown in Figure 1, subsidiary pole pieces 33 may be provided together with an anode 34, which prevents sputtering of parts other than the target.

CLAIMS

1. A magnetron sputtering apparatus including a vacuum chamber, a target mounted on a platen the target being disposed in the vacuum chamber on one side of the platen, a magnetic array mounted for rotation about an axis adjacent the other side of the platen, the array being so configured and disposed relative to the target such that the magnetic field on the one side of the target at the axis of rotation is non-zero.

2. Apparatus as claimed in Claim 1, wherein the component (B_H) of the magnetic field parallel to the target surface in the direction of increasing absolute field is at least 30% of the orthogonal component (B_V).

3. Apparatus as claimed in Claim 2, wherein B_H is greater than 50% of B_V.

4. Apparatus as claimed in any one of the preceding claims, wherein the array is constructed such that at some stage in each cycle the magnetic field on the one side of the target at any point on the target is non-zero.

5. Apparatus as claimed in Claim 4, wherein the component of the magnetic field parallel to the target B_H is at least 30% of the orthogonal field B_V component at any

point on the target at some stage in each cycle of the array.

6. Apparatus as claimed in claim 5, wherein the B_H is greater than 50% of B_V.

7. Apparatus as claimed in any one of the preceding claims, wherein the target is generally circular and co-axial with the axis of rotation and the array is eccentric with respect to the axis.

8. Apparatus as claimed in Claim 7, wherein the array is further mounted for planetary motion about the axis of rotation.

9. Apparatus as claimed in Claim 7, wherein the magnetic array has inner and outer generally D-shaped pole pieces.

10. Apparatus as claimed in Claim 9, wherein the axis of rotation passes through the inner pole piece.

11. Magnetron sputtering apparatus including a vacuum chamber, a target disposed in the chamber, a magnetic array for forming a tunnel-shaped field passing through the target and a motor for rotating the array, the motor and the array being disposed outside the vacuum chamber.

12. Apparatus as claimed in Claim 11, wherein the target is mounted on a heat sink platen which forms at least part of the wall of the chamber.

13. Apparatus as claimed in Claim 11 or Claim 12, wherein the magnetic array is disposed in a further chamber for at least partial evacuation.

14. Magnetron sputtering apparatus substantially as hereinbefore described with reference to Figure 1 or Figure 1 in combination with any one of the Figures 2 to 5.

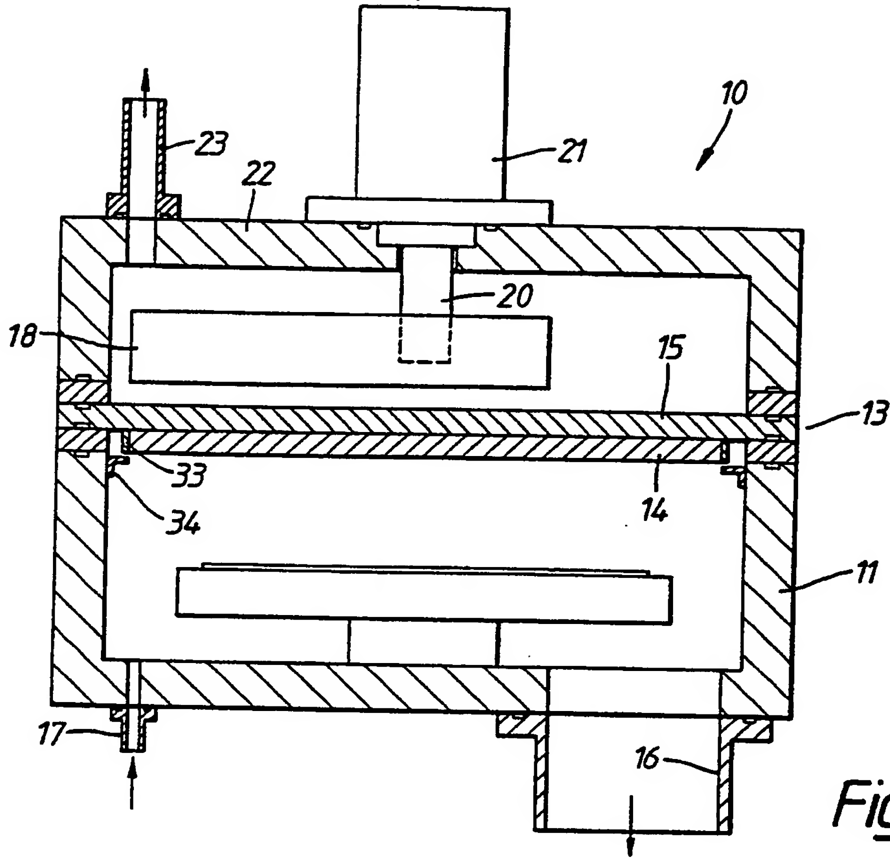

Fig.1.

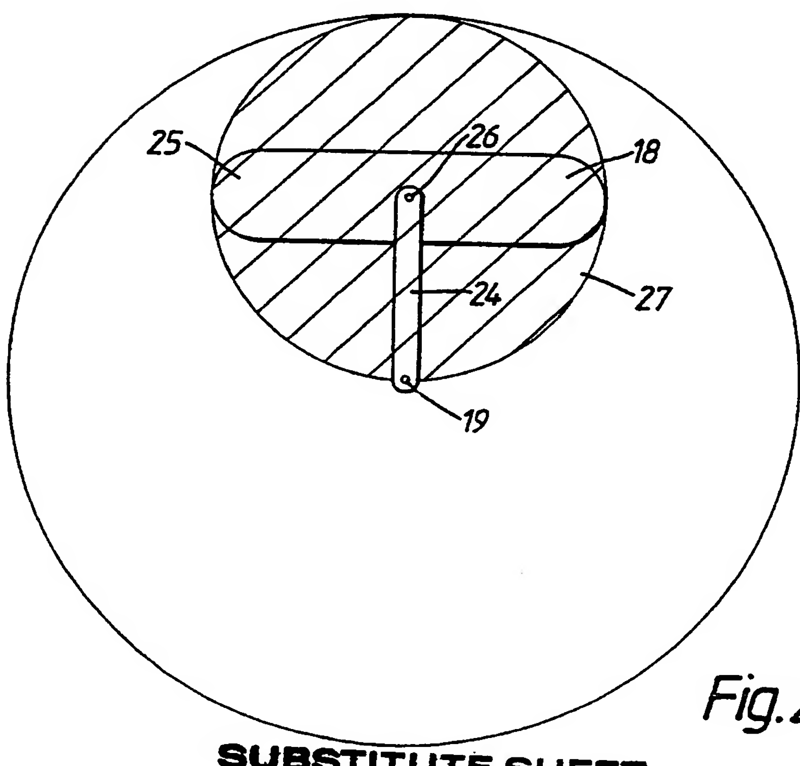

Fig.2.

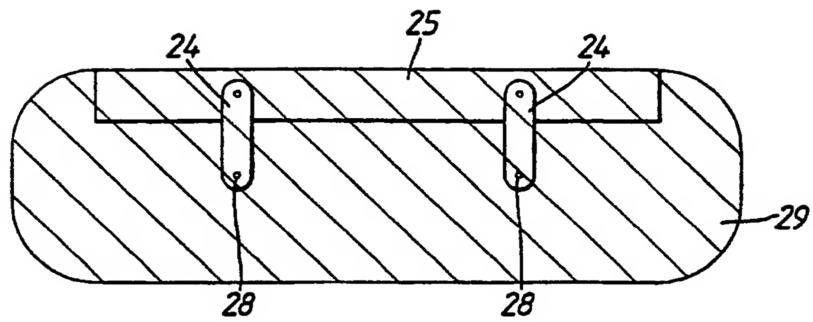

Fig.3.

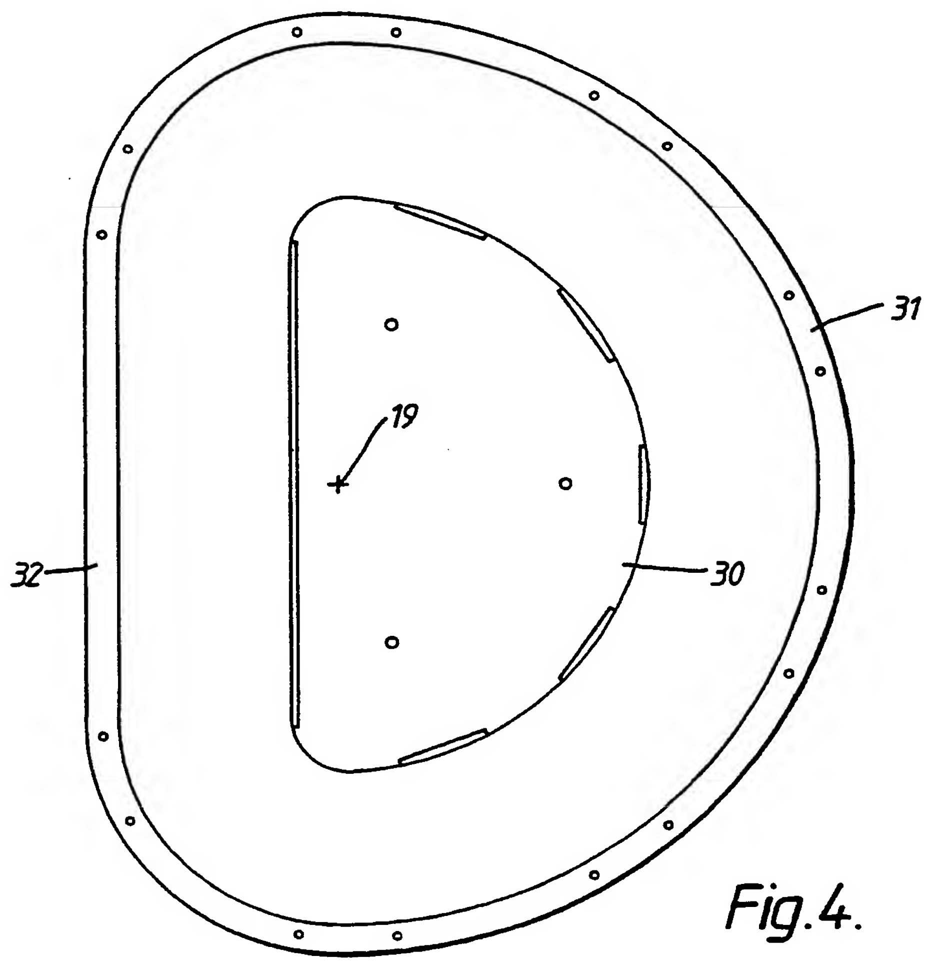

Fig.4.

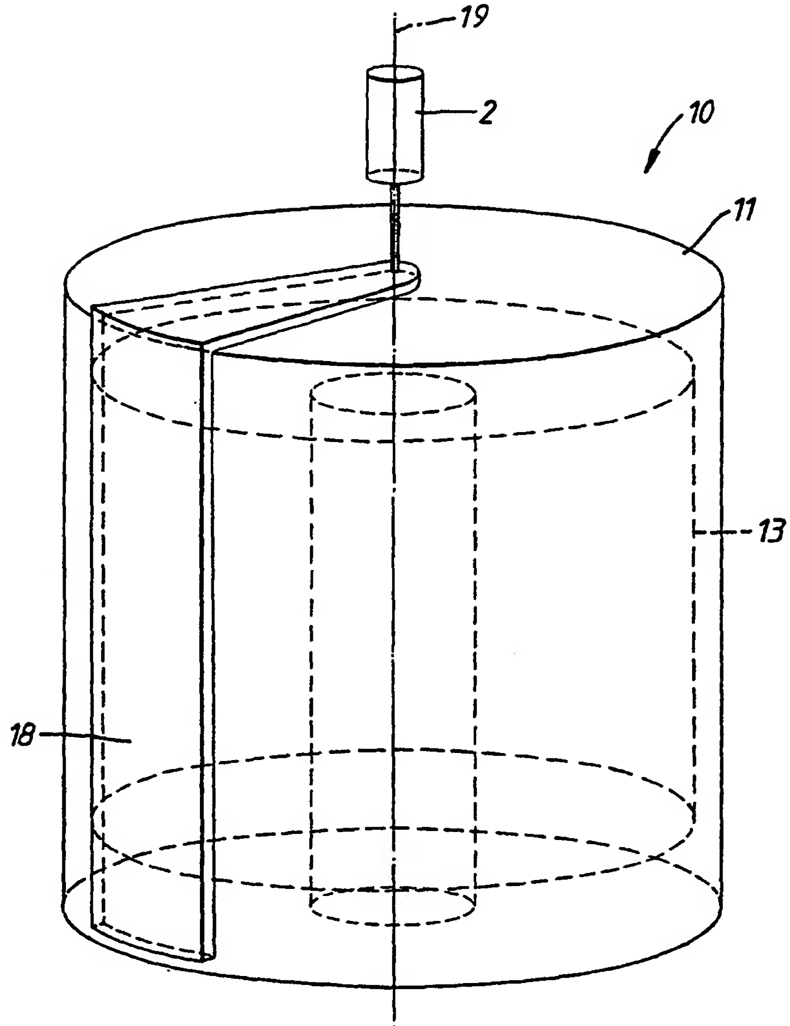

Fig.5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/00633

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01J37/34

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H01J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	PATENT ABSTRACTS OF JAPAN vol. 9, no. 28 (C-264)(1751) 06 February 1985, & JP-A-59 173265 (FUJITSU K.K.) 01 October 1984, see the whole document ---	1-7
X	PATENT ABSTRACTS OF JAPAN vol. 10, no. 280 (C-374)(2336) 24 September 1986, & JP-A-61 99673 (TOKUDA SEISAKUSHO K.K.) 17 May 1986, see the whole document ---	1, 7, 11
X	EP,A,211412 (FUJITSU K.K.) 25 February 1987 see page 3, column 3, lines 25 - 52; figures 3, 6 see page 4, column 6, lines 30 - 56 ---	1, 4, 7, 11, 12, 14
	-/--	

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
31 JULY 1990	28. 08. 90
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	EP,A,169680 (VARIAN ASSOCIATES) 29 January 1986 see page 5, line 25 - page 7, line 16; figures 1-5, 10, 11 see page 9, line 11 - page 11, line 22 ---	1, 4, 7, 8
A	EP,A,248244 (LEYBOLD-HERAEUS) 09 December 1987 see claim 1; figure 1 ---	1, 9, 10
A	EP,A,213922 (VARIAN ASSOCIATES) 11 March 1987 see page 9, line 31 - page 10, line 17; figure 1 ---	1, 8

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

PCT/GB 90/00633
SA 36669

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP-A-213922	11-03-87	JP-A- 62047478 US-A- 4714536	02-03-87 22-12-87

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